1 Tasmanian Wolf (*Thylacinus cynocephalus*), from Tasmania, purchased on April 18th.

2 Bearded Vultures (*Gypaëtus barbatus*), from Europe, purchased on April 9th.

4 Mortier's Water-Hens (*Tribonyx mortieri*), from Tasmania, purchased on April 18th.

Mr. Ernest Gibson, F.Z.S., exhibited a skin of *Felis geoffroyi* and made some remarks on the distribution of the animal.

The following papers were read :—

1. Observations on the Anatomy and General Biology of some Members of the Larger Cetacea. By D. G. Lillie, B.A., Hutchinson Research Student of St. John's College, Cambridge *.

[Received March 16, 1910.]

(Plate LXXIV.† and Text-figures 69–78)

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I. Introduction.

Within the past seven years six whaling stations have been established in various outlying parts of the British Isles. Four stations have been opened on the mainland of Shetland, one in North Harris in the Hebrides ‡, and one on the island of South Innishkea in the west of Ireland. Mr. R. C. Haldane §, of

* Communicated by Dr. Hans Gadow, F.R.S., F.Z.S.

† For explanation of the Plate see p. 792.

‡ For an admirable short account of the history of whaling and of its recent establishment in Scotland, see two papers by the late Thomas Southwell : Annals of Scottish Nat. Hist. 1904, vol. xiii. p. 77 ; and Annals & Magazine of Nat. Hist. ser. 7, vol. xvi. 1905. See also Lillie, Proc. Cambridge Phil. Soc. vol. xv. pt. iv. p. 347.

§ R. C. Haldane, Annals of Scottish Nat. Hist. 1901–1909.

Lochend, Shetland, availing himself of the opportunities thus offered, has collected and published much information relating to the larger Cetacea captured in Scottish waters since the opening of these whaling stations.

Hitherto, our knowledge of whales has been chiefly derived from isolated specimens stranded from time to time in various localities around the coasts of civilised countries. Some of these, though often in an advanced state of decay, have been examined by zoologists, and a few observations have been added to the large though scattered Cetacean literature. The fact that the whaling industry has been confined to the wildest regions of the earth and carried on under the severest conditions of physical privation has prevented other than chance observations of this nature being made.

The establishment of whaling stations near our shores should give a new impetus to the study of Cetology and induce competent observers to visit the stations during the whaling seasons. It may be hoped that new light will be thrown upon the many obscure problems in the biology of whales before these much hunted animals become too scarce.

During the spring of 1908 a whaling station was opened in the west of Ireland, by the Arranmore Whaling Company, on the island of South Innishkea off the coast of Co. Mayo; and a certain gentleman, who wishes to remain anonymous, prompted by considerations such as the above, came forward with a sum of money for the encouragement of the study of the Irish Cetacea. This fund, which was added to by others, was placed in the hands of Dr. S. F. Harmer, F.R.S., Keeper of Zoology in the British Museum (Natural History), who was asked to find someone to visit the Irish station for as long a period as possible during the summer of 1909 for the purpose of studying the anatomy, the specific characters, the general biology, and other questions of scientific interest relating to the larger Cetacea. I had the good fortune to be chosen for the work, and accordingly went to Innishkea on the 6th of July 1909 and remained there until the 26th of August, a period of seven weeks.

This visit took place about the middle of the whaling season, which begins early in May and continues up to the end of September. The capture of whales last year was very intermittent and depended largely on the weather. During the first part of my stay at Innishkea the weather was unusually rough for July and only one whale was caught in four weeks, while in the last fortnight I saw nearly thirty whales brought to shore.

The huge size of the animals makes any examination of them very difficult, even at a whaling station with all the necessary appliances for their dissection at hand. The length of the specimens seen at Innishkea varied between the limits of 50 and 80 feet in a straight line. Any whale under 40 feet is, according to the whalers, not worth shooting. The whalers have a definite method of cutting up a whale which no doubt is best suited to their purpose, though from the point of view of the anatomist the

process leaves much to be desired. The latter has to make the best of the operations however, and it is so essential in the whaling trade to dispose of the whales as rapidly as possible, while the oil is fresh, that the whalers can hardly be expected to study the needs of the anatomist. A whole animal 70 feet in length will often disappear completely in the course of a morning.

When a number of whales are brought in at the same time, as is often the case, the zoologist is not greatly benefited, for they are all anchored to buoys at some little distance from the shore, and brought to the "flensing slip" one by one to be stripped of their whalebone and blubber. The carcases are then taken back to the buoy to wait until they can be further dealt with. This method of procedure is rendered necessary on account of there being no room for more than three or four whales on the "flensing slip" at the same time.

The whales are artificially inflated with air directly they are killed, and they are then easily towed home by the whaling steamer. This inflation is often a source of great inconvenience to the anatomist, since portions of the viscera are torn away and shot out of the body-cavity when the body-wall is pierced by the flensing knife.

Enough has been said to show that to the scientific man a whaling station does not pretend to offer the advantages of unlimited time and comfort which are to be found in a laboratory. But at a station all the largest whales, with the exception of *Balæna mysticetus* and *Rhachianectes glaucus*, can usually be seen within the space of three months. Very frequently several individuals of different species can be examined and compared as regards their external and internal characters. The material is often sufficiently fresh for histological study, which, on account of the gigantic size of the animals, should prove of considerable interest. Moreover, exceptional opportunities are offered to the naturalist of going out to sea in the whaling steamers. Many interesting observations upon the habits of the Cetacea could possibly be made by this means alone.

With regard to the smaller Cetaceans, since they are seldom killed by man at present, material is difficult to obtain; but the study of these animals is not at the moment so pressing as that of the rapidly decreasing larger forms.

Before passing to consider the observations resulting from my stay of seven weeks at Innishkea I wish to express my thanks to the anonymous donors who made the visit possible, and to many friends who have helped me to carry out the work.

My special thanks are due to Dr. S. F. Harmer, F.R.S., who has kindly read the proof-sheets, for entrusting me with the research and for his valuable help and advice. I would also express my hearty thanks to Mr. R. M. Barrington, F.L.S., for his kindness in many ways and for giving me the benefit of his local knowledge. I am under obligations to the Rev. W. S. Green, C.B., Chief Inspector of Fisheries for Ireland,

and to Mr. E. W. L. Holt for much kindness shown to me at Innishkea. I cannot express my thanks too warmly for the cordial help and hospitality accorded to me by Captain Arff-Pettersen, Mr. E. Christensen, and others at the Whaling Station. My sincere thanks are due to Mr. A. E. Shipley, F.R.S., for many kindnesses. To Dr. W. T. Calman I am indebted for the determination of the Crustacea. Finally, to Dr. H. Gadow, F.R.S., I am very deeply grateful for his valuable help with regard to several anatomical points.

II. The Species captured at Innishkea.

The catch of whales at Innishkea for the opening season of 1908 numbered 77, and was as follows*:

5 *Balæna biscayensis* Gray.
21 *Balænoptera musculus* Linnæus.
19 *Balænoptera sibbaldii* Gray.
31 *Balænoptera borealis* Lesson.
1 *Megaptera longimana* Rudolphi.

The total number of whales caught during the season of 1909 was 102. These consisted of five species. The numbers and average length of the individuals are given in the following table:—

Species.	Total number killed.	Number of Bulls.	Average length of Bulls.	Number of Cows.	Average length of Cows.
			ft. ins.		ft. ins.
Balæna biscayensis Gray	5	4	43 6	1	43 0
Balænoptera musculus Linnæus.	56	27	58 3	29	60 0
Balænoptera sibbaldii Gray	27	13	65 5	14	66 5
Balænoptera borealis Lesson	9	4	43 0	5	42 0
Physeter macrocephalus Linnæus	5	5	55 7		

Thus the list of species taken off Innishkea is as follows:—

Balæna biscayensis Gray,
Balænoptera musculus Linnæus.
Balænoptera sibbaldii Gray,
Balænoptera borealis Lesson,
Megaptera longimana Rudolphi,
Physeter macrocephalus Linnæus,

* Hoblane, Annals of Scottish Nat. Hist. April 1909, p. 68.

and includes all the largest known species of whales with the exception of *Balæna mysticetus* Linnæus and *Rhachianectes glaucus* Cope. Several smaller Cetaceans are seen off the west coast of Ireland, but they are not killed by the whalers. These include *Balænoptera rostrata* Gray, and some members of the subfamily Ziphiinæ and the family Delphinidæ.

The specimens of *Balæna biscayensis* Gray, killed last summer, were taken during the first fortnight of June. This species is said by the whalers to leave our shores after the end of June. *Balænoptera musculus* Linnæus was equally plentiful from the beginning of May till the end of the season. *Balænoptera sibbaldii* Gray was taken from the end of June till September. The captures of *Balænoptera borealis* Lesson, were restricted to the last half of May and the first half of June, the last specimen being caught ten days before the first *B. sibbaldii* Gray was taken. This whale is said to leave our shores upon the arrival of *B. sibbaldii*. The Sperm Whales (*Physeter macrocephalus* Linnæus) were captured between the middle of June and the end of July. If detailed records of the captures of whales continue to be kept for the Irish stations * to compare with those published by Mr. Haldane for the Scotch stations, we may hope, by this means, to throw some light upon the migrations of these creatures.

During my stay at Innishkea the following whales were captured: 21 specimens of *Balænoptera musculus* Linnæus, 15 of which were examined; 20 individuals of *B. sibbaldii* Gray, 15 of which were examined; and two male Sperm Whales (*Physeter macrocephalus* Linnæus), both of which were examined. The results obtained from the examination of these whales will now be described.

III. The Occurrence of Hairs in Whales.

The distribution and significance of the scanty hairs of the Cetacea do not appear to have been hitherto studied in the detail they deserve. They have been vaguely referred to as occurring on the jaws of some adult forms †. Sometimes they have been found on the fœtus only.

In two adult Sperm Whales (*Physeter macrocephalus* Linnæus) seen at Innishkea, no trace of hairs could be found on any part of the animals even after careful searching.

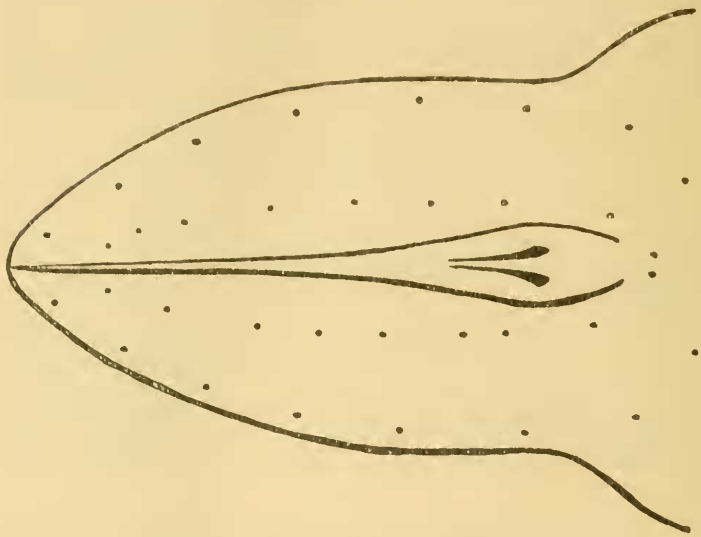
In the case, however, of the Rorquals *Balænoptera musculus* Linnæus, and *B. sibbaldii* Gray, some 15 individuals of each species were examined, and it was found that a definite distribution of hairs could be made out in each case. Four rows of straight, white, bristle-like hairs from half an inch to an inch in length occur on the dorsal surface of the beak or facial region of

* A second Irish station is expected to be opened for the season 1910.

† Knox, Proc. Roy. Soc. Edinb. i. 1833–4. Eschricht & Reinhardt, "Om Nordhvalen," Copenhagen, 1861. Collett, Proc. Zool. Soc. 1886, p. 255. Cunningham. Proc. Zool. Soc. 1876, p. 680. Clark. Proc. Zool. Soc. 1876, p. 688.

the head (see text-fig. 69). These consist of two inner rows on either side of the median ridge which bears the blow-holes or external nares, and two outer rows following the edges of the beak from points just behind the blow-holes to its anterior extremity. The average number of hairs in each row is about eight. The hairs in each row occur at irregular intervals, but they always keep to the above mentioned lines of distribution whether there are more or less than eight hairs forming a row.

Text-fig. 69.



Dorsal surface of the beak of *Balænoptera sibbaldii* Gray, showing hairs.

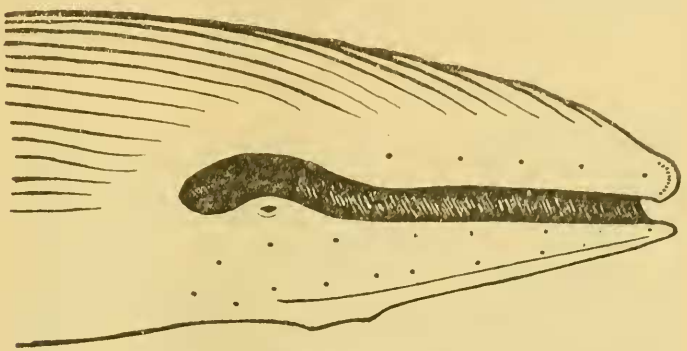
On each side of the lower jaw (text-fig. 70) there was a row of some five or more hairs running from the tip of the mandible along the middle line of the outer edge of each ramus to a point just in front of the eye. At the extreme anterior end of the mandible (see text-fig. 70), over the ligamentous junction of the rami, there were also two vertical rows of hairs set at right angles to those last mentioned. These occur close together and run parallel to each other from the upper to the under surface of each ramus. The hairs in these two rows are placed closer together than in the others, there being generally about fourteen hairs in each row.

The relations of the hairs to the epidermis and adjoining layers in *Balænoptera musculus* Linnæus, have been figured and described by G. O. Sars* in a paper published in 1865; but further work requires to be done in order to determine whether they possess a tactile function or not.

* Sars, Vidensk.-Selskabets Forhandlinger for 1865.

On looking through the Cetacean literature there appears to be no record of the occurrence of hairs in adult Odontocetes. It would seem that the presence of hairs in the adult is restricted to the Whalebone Whales; and their retention and distribution over the beak and mandible in these forms may be due to their possessing a tactile function and thus serve to indicate to the animal the presence of its food. The small size of the Crustacea which generally form the food of the Mystacoceti make them difficult to see, and since the olfactory organs of the Cetacea are very reduced, the occurrence of tactile hairs over the oral region may be an advantage, as the small food-animals might brush against them and thus inform the whale when to open its mouth.

Text-fig. 70.



Lateral view of the head of *Balænoptera sibbaldii* Gray, to show the hairs.

The top of the snout of a whale is, of course, only the prolonged upper lip, where one would naturally look for vibrissæ. In one of the figures given by Sars in the paper above mentioned, what appears to be a nerve is seen traversing the blubber at the base of the hair; which would point to a tactile function. On this theory, the food of the Odontocetes being of a larger size the presence of tactile hairs is not so obviously required, and hence the hairy covering has entirely vanished in the adult forms of these whales.

On the other hand it is also conceivable that the vibrissæ, because of their relative stoutness, should be the last hairs to disappear; and the fact that they have reached a further stage of degeneration in the Odontocetes than they have in the Whalebone Whales may be purely accidental.

IV. The Auditory Organ of *Balænoptera*.

The auditory apparatus in several individuals of *Balænoptera musculus* and *B. sibbaldii* was examined with some difficulty. The parts of the ear agreed fairly well in both these species with

those parts of the auditory organ, in *Balænoptera rostrata*, which were described by Drs. Carte and Macalister* in their excellent paper on the anatomy of a member of that species published in 1867. Dr. Dwight † has also described the bones of the auditory organ of *B. musculus* at some length in a paper published in 1872. It will thus be only necessary briefly to recapitulate here the parts of the organ which are already known and to add some observations which appear to be new.

The opening of the external auditory meatus on the surface of the head is a relatively small slit situated at a short distance behind the eye in a horizontal line with the commissure of the lips. There is no trace of a pinna. The auditory canal is continued backwards from this aperture until it reaches as far as the zygomatic process of the squamosal bone where it turns inwards and, increasing somewhat in diameter, proceeds along a groove in the squamosal bone (text-fig. 71, *Sq.*[1]) which winds round the posterior border of that bone to reach the tympanic membrane. The diameter of this tube towards its inner and wider extremity was about one and a half inches in the two species under consideration.

The tympanic membrane (Pl. LXXIV. fig. 1) seems to have escaped the notice of previous observers. It is highly modified and is a sac-like structure not unlike the finger of a glove. The sac (Pl. LXXIV. fig. 1, *f*) is about three inches long and three-quarters of an inch in diameter and tapers to a rounded point at the outer or distal end. The walls of the sac are about one-tenth of an inch in thickness, and consist chiefly of white fibrous tissue and yellow elastic tissue. No nerve-cells or fibres and no muscle-fibres have been found up to the present. From the upper surface of the sac in the median line a ligament about an inch long and 5 mm. in diameter projects forwards towards the tympanic cavity. The ligament is continued along the sac in the opposite direction as a ridge. The total length of the tympanic sac and ligament is about four inches. The mouth of the sac opens into the tympanic cavity, while the outer portion projects into the external auditory meatus. The inner extremity of the latter joins the rim of the sac (Pl. LXXIV. fig. 1, *h*). The ligamentous process passes under the junction of the malleus and incus, and becomes attached at its proximal end to the very much reduced manubrium of the malleus. The malleus is fused to the tympanic bone, as has been already pointed out by Drs. Carte and Macalister. Thus in *Balænoptera* the tympanic membrane has become a sac-like organ, which projects outwards and is attached by a ligament to a rigid process of the tympanic bone—this process being the malleus.

In the external auditory meatus of all the individuals examined at Unalaska there was a solid plug of wax-like substance of fairly definite size and shape which does not seem to have been hitherto described. This plug (Pl. LXXIV. fig. 2) was usually about

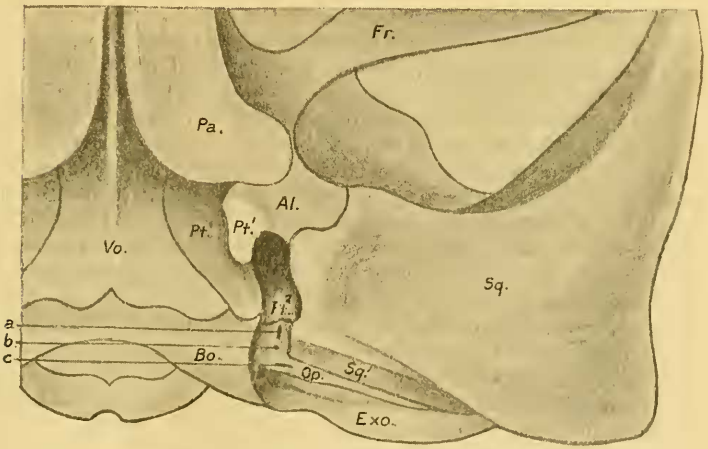
* Carte & Macalister, Phil. Trans. 1867, p. 252.

† Dwight, Memoirs Boston Soc. Nat. Hist. 1872, vol. ii. p. 225.

5 inches long and $1\frac{1}{2}$ inches broad at the wider end. It consisted of a deposit of ear-wax, which formed a coat to the outer surface of the tympanic membrane in that region where the latter projected into the external auditory meatus. The deposit formed a solid mass, which could easily be detached from the tympanic membrane. The inner portion of the plug had the form of an oval cup (Pl. LXXIV. fig. 2, *a*), measuring about $1\frac{1}{2}$ inches across the broadest part and approximately 1 inch deep. The outer portion, however, formed a solid thin flattened rod about 4 inches long and 1 inch broad (Pl. LXXIV. fig. 2, *b*). The auditory canal appeared to be full of water, in which the tympanic membrane was immersed, with the attached plug of wax lying in a horizontal position. The total length of the membrane and plug thus projecting into the auditory canal was about 6 inches (Pl. LXXIV. fig. 3).

The Cetacea have a remarkable depression on the base of the cranium on each side of the median line (text-fig. 71).

Text-fig. 71.



Ventral view of left posterior portion of the skull of *Balænoptera musculus* Linnæus The tympanic bone has been removed.

Fr.=Frontal; *Pa.*=Palatine; *Vo.*=Vomer; *Al.*=Alisphenoid; *Pt.*=Pterygoid; *Pt.*¹=Pterygoid plate of alisphenoid; *Pt.*²=Portion of pterygoid, forming roof of pterygoid fossa; *Sq.*=Zygomatic process of squamosal; *Sq.*¹=Zygomatic process of squamosal, forming roof of groove in which lies the inner portion of the external auditory meatus with the plug of ear-wax; *a*, anterior pedicle for attachment of tympanic bone, situated on pro-otic portion of periotic; *b*, fenestra ovalis, situated on the labyrinthic segment of periotic; *c*, posterior pedicle of tympanic bone, situated on opisthotic portion of periotic; *Op.*, opisthotic portion of periotic; *Bo.*, basioccipital; *Exo.*, exoccipital.

In *Balænoptera* these depressions are bounded posteriorly by the projecting edge of the exoccipital, externally by the base of the zygomatic process of the squamosal, on the inner side behind by

the prominent edge of the basioccipital. The anterior portion of the inner side of this depression and the front of the recess are bounded by the pterygoid and alisphenoid bones, which are fused together; the latter also form the roof of the anterior half of the depression. Thus the anterior portion of the cavity is bounded on three sides by the pterygoid and externally by the squamosal, and is known as the pterygoid fossa.

In this recess the united tympanic and periotic* bones lie. The latter consists of three parts: an anterior or pro-otic, a central or labyrinthic, and a posterior or opisthotic. The anterior or pro-otic bone resembles a three-sided pyramid with its apex pointing forwards and projecting into a cavity in the squamosal bone above the roof of the pterygoid fossa.

On the inferior surface of the pro-otic, at its posterior end, there is a longitudinally flattened pedicle which unites with the anterior extremity of the tympanic bone. Just behind this anterior pedicle of the tympanic—that is, between the pro-otic portion and the central or labyrinthic—there is a groove running in a transverse direction. This furrow forms the roof of the auditory meatus. The central or labyrinthic portion is the smallest of the three divisions of the periotic, and it contains the vestibule, the cochlea, and the diminutive semicircular canals. The inferior surface of this bone is dome-shaped and forms the roof of the tympanic cavity. The fenestra ovalis is situated in the depression which marks the outer border of this bone on the under side. The fenestra rotunda is placed some little distance behind the fenestra ovalis, and is separated from the latter by a ridge which forms the posterior boundary of the tympanic cavity above. The fenestra rotunda is thus on the posterior surface of the labyrinthic segment, and thus outside the tympanic cavity. The superior surface of the labyrinthic bone is irregular in shape and is turned towards the cranial cavity. Two foramina open on this surface—the aqueductus Fallopii anteriorly and the internal auditory meatus posteriorly. The aqueductus perforates the bone and opens at the base of the labyrinthic segment, and is continuous with a groove in the opisthotic division. At the posterior end of the labyrinthic the opisthotic segment extends outwards; it is constricted at its origin, but broadens and expands towards its extremity between the squamosal and exoccipital bones almost at right angles to the pro-otic portion. In fact, the labyrinthic may be said to lie at the angle formed by the pro-otic and opisthotic. The tympanic segment is united to the ends of these two bones by pedicles, which are flattened in the direction of their length. Thus the posterior pedicle is situated on the inferior surface of the opisthotic, near its junction with the labyrinthic, and is at right angles to the anterior pedicle.

The tympanic bone† (Pl. LXXIV. fig. 3, *d*), which is attached to the periotic as described above, is usually about five inches long

* Carte & Macalister, Phil. Trans. 1867, pl. vi. fig. 11.

† Carte & Macalister, *loc. cit.* pl. vi. fig. 10; pl. vii. fig. 6.

and shaped like a cowrie shell. It occupies the posterior half of the depression, into which it fits fairly closely (text-fig. 71, *a*, *c*), its outer inferior surface being level with the projecting edge of the basioccipital, the pterygoid fossa lying immediately in front. The tympanic bone may be said to have an inner and an outer surface, which meet below. The inner surface is flat, its lower edge lying near, but not touching, that of the projecting process of the basioccipital; its upper edge is smooth and rolled into the cavity of the bone. The outer side of the tympanic is rounded, with the convexity pointing outwards. The upper edge of this outer side forms an irregular extended lip, which gives rise to the anterior and posterior pedicles. On this lip, immediately behind the anterior pedicle and at right angles to it, there is a ridge projecting upwards and nearly touching the periotic. The inner edge of this ridge is continuous with the processus longus of the malleus, the malleus thus being fused to the tympanic bone. This process, which runs parallel to the posterior pedicle, together with the latter, form the sides of the auditory meatus.

The malleus has been described by Drs. Carte and Macalister*, and is stated by these authors to be fused to the tympanic bone by the handle or manubrium; whereas Dr. Dwight† regards that portion of the malleus which has co-ossified with the bulla as the processus longus or gracilis. The latter would seem to be the correct interpretation judging from the mode of attachment of the tympanic membrane. This structure was apparently lost or had decayed in the specimens dissected by the above-mentioned writers, so they could only guess at the relationship of the parts. The manubrium is reduced to a short process, slightly hooked at its distal end (Pl. LXXIV. fig. 1, *b*), on the ventral surface of which is attached the ligament of the tympanic membrane. This is the only attachment of the membrane to the malleus. The rim of the tympanic membrane sac is joined to the inner extremity of the external auditory canal. The processus longus or gracilis (Pl. LXXIV. fig. 1, *c*) is well developed, and is fused to the inner edge of the lip of the tympanic bulla. The incus and stapes have been described by previous writers‡, and are morphologically similar to those found in other Mammals.

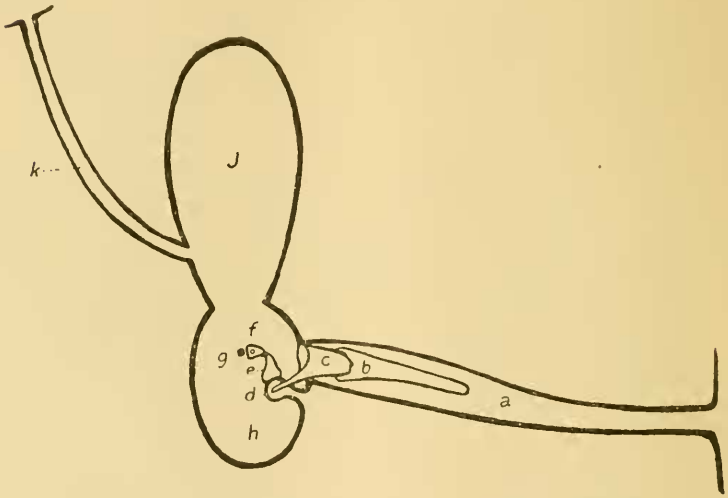
At the anterior end of the tympanic cavity, in front of the anterior pedicle of the tympanic bone, there is an opening which communicates with the pterygoid fossa. This may be regarded as the enlarged inner end of the Eustachian tube. The pterygoid fossa, which measures from 6 to 8 inches in length, about 4 inches in width, and 4 inches in depth, is also a portion of the Eustachian tube, for it is lined by the same mucous membrane as the tympanic cavity and the Eustachian tube proper. The latter is a relatively narrow canal, about three-quarters of an inch in diameter, which opens out of the floor of the pterygoid fossa and winds along a

* Carte & Macalister, *loc. cit.* p. 254.
† Dwight, Mem. Boston Soc. Nat. Hist. 1872, vol. ii. p. 226.
‡ Carte & Macalister, *loc. cit.* p. 254; Dwight, *loc. cit.* p. 226.

groove on the inner side of the pterygoid plate of the alisphenoid (text-fig. 71, Pt.[1], p. 777) to open into the alveolated nasopharyngeal chamber near the junction of the nares. This tube is about one foot in length in the larger specimens. The mucous membrane, which lines the Eustachian tube and is continued into the pterygoid fossa and tympanic cavity, lies directly on the bony walls of these cavities and covers over the ossicles.

The cavities of the middle ear are probably filled with air through the Eustachian tube (text-fig. 72), while the external ear appears to be filled with water. The pressure of the water upon the tympanic membrane when the whale dives must be considerable, and it is

Text-fig. 72.



Diagrammatic view of the outer and middle ear of *Balænoptera*.

a = external auditory meatus; *b* = plug of ear-wax; *c* = tympanic membrane attached to malleus by ligament; *d* = malleus fused to tympanic bone; *e* = incus; *f* = stapes; *g* = fenestra ovalis; *h* = tympanic cavity; *J* = pterygoid fossa; *k* = Eustachian tube.

curious that the membrane should be concave on its inner side instead of on the outer side. The sac-like membrane, being connected by a ligament to the rigid malleus, cannot have a vibrating function. The animal probably fills the middle ear with air on coming to the surface to breathe. When the creature dives, this air is imprisoned by the closing of the Eustachian tube. The walls of the latter are provided with a strong sphincter muscle. The air in the Eustachian tube would be forced into the pterygoid fossa and tympanic cavity when the tube was compressed, and would inflate the sac-like tympanic membrane. This air would be approximately at atmospheric pressure. The increase of pressure

produced by the water on the external surface of the membrane as the animal dived would tend to compress the walls of the sac. There may be some means by which this increased pressure is made known to the animal, and thus enable the curiously modified tympanic membrane to serve as a pressure-gauge; but it is not possible to assign any function to the structure at present.

The whale probably receives sound-vibrations by means of vibrating bony surfaces, after the manner of fishes. The tympanic bulla is a relatively dense and heavy sounding-box, fastened to the periotic bone by two thin pedicles, so that it could be easily set in vibration. The bulla is connected with the fenestra ovalis by the chain of ossicles, the auditory apparatus being thus independent of the tympanic membrane, which may have some other function, possibly that of a pressure-gauge.

The description of the ear of *Balæna mysticetus* given by Home* in 1823 seems to correspond to some extent with the above account of that organ in *Balænoptera*. The ear of the Odontocetes appears to be more like that of ordinary Mammals †.

V. The Asymmetry of the Odontocete Skull.

It has long been recognized that a want of symmetry exists in the Odontocete skull, centred round the nasal region; but authorities seem still to be at a loss to account for this irregularity. Mr. Beddard ‡ sums up the difficulty thus:—"It is easier to say that the asymmetry, being, as it is, chiefly developed in the regions of the blow-holes, has something to do with these structures, than to find any adequate reason for connecting the two." From an examination of the skull alone an explanation certainly does not present itself very readily. But when the anatomy of the head and neck of a symmetrical Mystacocete, such as *Balænoptera musculus* Linnæus, is examined, and the relations of all the parts studied and compared with those of an asymmetrical Odontocete, such as *Physeter macrocephalus* Linnæus, the problem becomes greatly simplified, and a solution seems to offer itself.

In the Cetacea the arytenoid and epiglottidean cartilages form a long, rigid, cylindrical tube, a continuation of the larynx, which rises up through the floor of the pharynx like a pillar and is thrust up between the alveolated walls of the nasopharyngeal chamber, which form the roof of the pharynx in this region. In the larger whales this pipe is about one foot in length. A somewhat similar pipe-like epiglottis, connecting the larynx with the posterior nares also occurs in the Marsupials and Ungulates; but it is less pronounced than in the Cetacea.

In the case of the symmetrical Mystacocetes this tube is

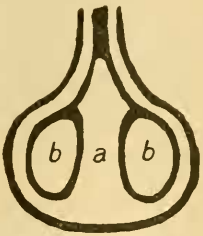
* Home, 'Lectures on Comparative Anatomy' (1823), Vol. iii. Lect. IX., Vol. iv. Tabs. c. & ci.

† Hunter, Phil. Trans. 1787, p. 430.

‡ Beddard, 'A Book of Whales,' p. 49.

situated in the middle of the pharynx. The food of these whales, consisting as it does of small Crustaceans, can readily enter the comparatively narrow pharynx and find a passage down the pharynx on each side of the pipe (see text-fig. 73).

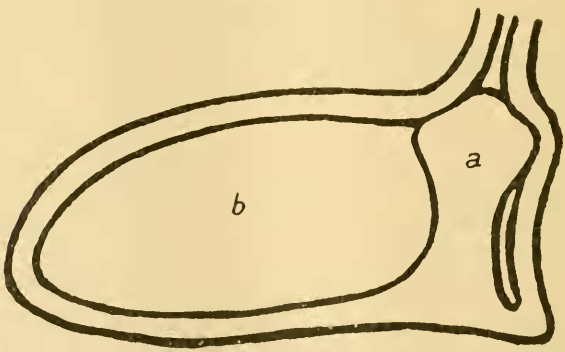
Text-fig. 73.



Transverse section (diagrammatic) of the pharynx of a Mystacocete.
a = epiglottis; b = food-passage.

In the Odontocete *Physeter* the pharynx is fully four or five times as large as that of a *Balænoptera* of the same length, and the pipe-like epiglottis, instead of being placed in the middle of the pharynx, is on the left side close against the left wall of the latter. The pipe passes up into the nasopharyngeal chamber, which has alveolated walls; as in *Balænoptera*, this

Text-fig. 74.



Transverse section (diagrammatic) of the pharynx of *Physeter*.
a = epiglottis; b = food-passage.

chamber communicates with the posterior nares situated on the left side of the skull. The comparatively large animals eaten by this whale, which are always swallowed whole, pass down the spacious pharynx only on the right side of the pipe, which is close up against the left wall and leaves plenty of room for their transit (see text-fig. 74). Thus the pharynx of *Physeter* in the region of

the glottis is divided into a right half for the passage of food and a left half for respiration. This arrangement gives an asymmetrical form to the nasal regions of the skull.

Pouchet and Beauregard*, in their admirable memoir on the anatomy of the Sperm Whale, refer to the pipe-like epiglottis as being asymmetrically placed; but they state that it was situated on the right side of the pharynx, whereas in both the specimens of *Physeter* seen at Innishkea the pipe was undoubtedly on the left side. These authors appear to have attached no significance to the position of the epiglottis as bearing upon the asymmetry of the skull.

VI. Notes on the Species.

1. Balænoptera musculus Linnæus †.

The length, form, and proportions of all the specimens seen were in accordance with previous descriptions of the species.

Colour. There appeared to be two colour-types in this species, distinguished by the colour of the dorsal surface. In the more common type the colour of the dorsal surface was bluish black; in the other variety the dorsal surface was brownish black, almost sepia. This fact has been noticed by Mr. Haldane‡, who attributes the difference in colour to a light-effect; but it was sufficiently marked in all the individuals landed during my visit for them to be placed in either one or other of the two groups.

The asymmetrical colouring of the face was remarkably constant in all the specimens. On the right side the outer edge of the beak was white or light grey; on the left side the beak was entirely bluish black or sepia in colour, according to the variety which the individual belonged to. The anterior third of the baleen plates on the right side were invariably white, the remainder on that side being dark grey or black on the outer halves of the plates and becoming lighter in colour towards their inner edges. On the left side all the baleen plates were similar to the posterior plates of the right side. The bristles were invariably white all round the mouth, and not black as stated by Mr. Collett§ in his synopsis of the four northern species of *Balænoptera*. The lower jaw was white on the right side, and bluish black or sepia on the left side. The whole underside of the body, the right lower jaw, the inner side of the paddles, and the under side of the flukes of the tail were white in all cases. The roof of the mouth consists of a broad oval margin of white bristles surrounding a narrow strip of pink palate, and below, a pink tongue covered with dark grey mottling. Every specimen had whitish oblong spots distributed over the dark parts of the body, identical, except in

* Pouchet et Beauregard, Nouvelles Archives du Muséum (Paris), 3 sér. vol. iv 1892, p. 59, pl. iii.

† Known also as *B. physalus* Fabricius, *B. rorqual* Lacépède, *Physalus antiquorum* Gray.

‡ Haldane, Annals of Scottish Nat. Hist. 1908, p. 70.

§ Collett, Proc. Zool. Soc. 1886, p. 265.

size, with those figured and described by Mr. Collett* as occurring in *B. borealis*. The spots in *B. musculus* usually did not exceed 50 mm. in length.

Throat-grooves.—In several individuals of both *B. musculus* and *B. sibbaldii* the skin lining the grooves in the throat-region had a bright red appearance. It unfortunately did not occur to me at the time to ascertain the cause of this; but I am inclined to think that the red colour of the grooves may be due to their being very highly vascular, and thus helping to aërate the blood. The throat-grooves of *Balænoptera* occupy about half of the ventral surface of the body, extending from the anterior end of the mandible to the navel. In *B. musculus* there are about 100 of these grooves, in the other species about 60. The skin lining the furrows is extremely elastic. When unextended the grooves are about an inch in width; when extended they are often six inches wide. Thus they would give a large aërating surface. Undoubtedly the principal function of these elastic furrows on the throat is to increase the size of the mouth-cavity, so that a large volume of water containing Crustaceans can be taken in at each mouthful. The water is strained off through the whalebone plates, and afterwards the food is swallowed. In *Balæna* the mouth itself is very large, owing to the arched form of the skull, so that its capacity is naturally ample. Hence the absence of throat-grooves in the Right Whales. The function of the grooves as an aërating surface or external gill, if it occurs at all, would be a secondary one. This theory, however, would enable us to understand the extraordinary powers of remaining under water attributed to *Balænoptera* which will be referred to later in this paper.

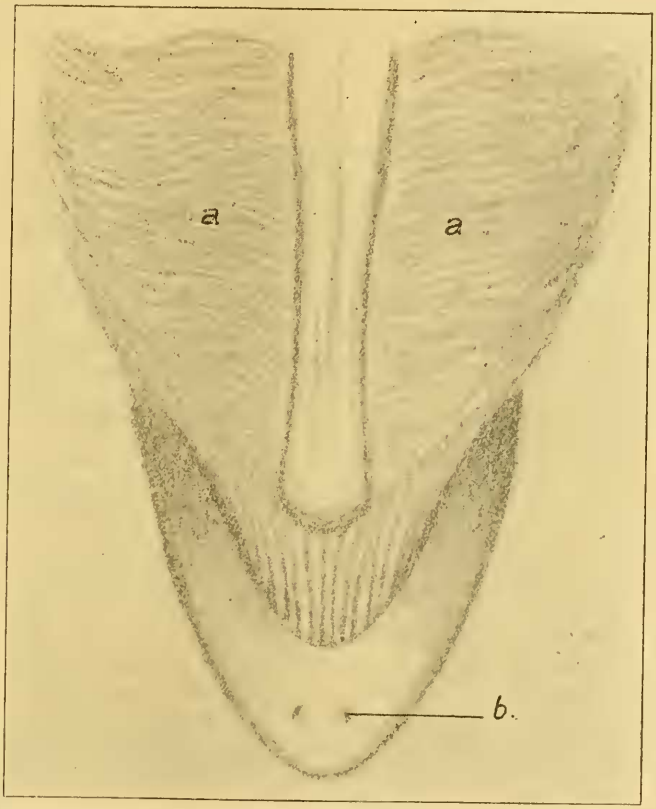
Jacobson's organ.—On the under surface of the snout, about half way between its extreme tip and the small anterior filaments of whalebone, there were two small apertures leading into narrow tubes which ended blindly about two inches from their mouths (text-fig. 75). These were the ducts of the organ of Jacobson. In *B. sibbaldii* they are only represented by two small depressions. In most Mammals these organs communicate with the nostrils, but in an adult *B. musculus* they are separated from the nostrils by a distance of some ten feet, and are interesting examples of the persistence of traces of an organ after it has become obsolete. It is just possible that the small ducts in *B. musculus* may have some function, but they were not equally well developed in all the individuals examined, and in one specimen they were reduced to mere depressions very much like those of *B. sibbaldii*.

Testes.—In a member of this species, 51 feet long, the testes were measured and found to be only 9 inches in length and 3 inches in diameter. In a specimen 60 feet long the testes were 2 feet 6 inches in length and nearly a foot in diameter. This shows that male members of this species reach maturity when between 50 and 60 feet long.

* Proc. Zool. Soc. 1886, p. 249, pl. xxvi. fig. 2.

Penis.—In the Cetacea the penis when not in use is capable of being entirely withdrawn into the body-cavity. The ventral surface of the body is thus left free from any protuberance which would hinder the animal in swimming. The testes remain permanently inside the body-cavity. The penis of an adult *B. musculus* measures from 5 to 6 feet in length when fully extended; it is about a foot in diameter at the base, tapering to a relatively fine point.

Text-fig. 75.



Ventral view of anterior extremity of the beak of *Balænoptera musculus* Linnæus
a = hairy inner surface of baleen plates; *b* = external openings of the organ Jacobson.

Food.—An examination was made of the stomach-contents of nearly all the specimens of this species caught during the months of July and August, and it was found that only one individual, killed on July 13th, had fed upon herrings. The alimentary

canals of all the others contained *Meganyctiphanes norvegica* M. Sars (formerly called *Nyctiphanes norvegica*). Other species of Euphausiidæ may have been present but only the above mentioned was definitely determined. In the pharynx these Crustaceans were found practically intact; in the stomach they were more broken up, and in the intestines they were reduced to a thick terra-cotta coloured fluid, the red colour being due to a red pigment commonly found in the Euphausiidæ.

Fœtuses.—On July 31st, 1909, two female *B. musculus* were killed, one was 63 feet long and contained a fœtus 1 foot in length. The other was 67 feet long and contained a fœtus 5½ feet in length. This tends to support the view that the species under consideration and possibly other species of *Balænoptera* have no definite breeding season.

Parasites.—The external surfaces of all the *B. musculus* examined were entirely free from parasites with the exception of the baleen plates. These were very frequently coated with the adult forms and nauplius larvæ of *Balænophilus unisetus* Amivillius. These remarkable Copepods have been found on the baleen plates of *B. borealis* and *B. sibbaldii* *, but this appears to be the first record of their occurrence on *B. musculus*.

2. Balænoptera sibbaldii Gray (*B. latirostris* Flower).

The external characters of all the Innishkea specimens were in agreement with the descriptions of the species given by previous observers.

The inside of the mouth, the baleen, bristles, palate and tongue were entirely black.

The forms of the paddles and dorsal fins of *B. sibbaldii* differ from those of *B. musculus*, as is shown by the diagrams (text-figs. 76 & 77). It would seem that the presence of a dorsal fin is restricted to the fast-swimming Cetaceans.

The contents of the alimentary canals were examined in the case of some ten individuals of this species, caught during August, and found to consist exclusively of *Meganyctiphanes norvegica* in all cases.

A young male member of this species, 63 feet long, was killed while following the mother and feeding upon her milk. The specimen had Crustaceans in its stomach, showing that it did not depend entirely upon the mother for food. The young of *B. sibbaldii* are said to be between 20 and 30 feet in length at birth, so, unless the period of lactation is unusually prolonged, this would point to a comparatively rapid growth and development in the larger Cetacea as is maintained by Mr. Haldane †. If the period of lactation continued, as is generally supposed, for one year the animal would increase in size to the extent of over 30 feet in its first year of life.

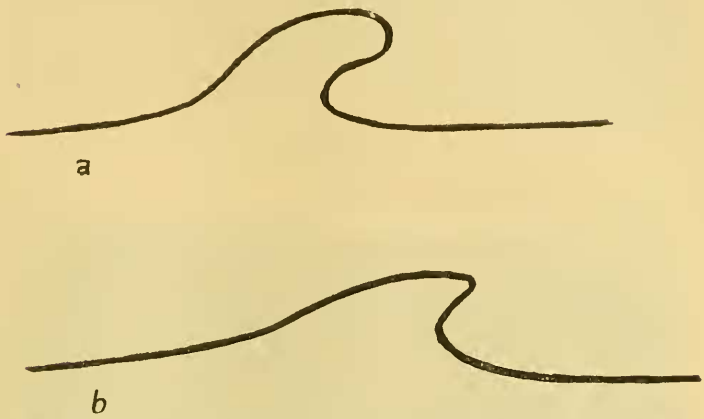
The external surfaces of all the individuals of this species were

* Collett, Proc. Zool. Soc. 1886, p. 243.

† Haldane, Annals of Scottish Nat. Hist. April 1905, p. 69.

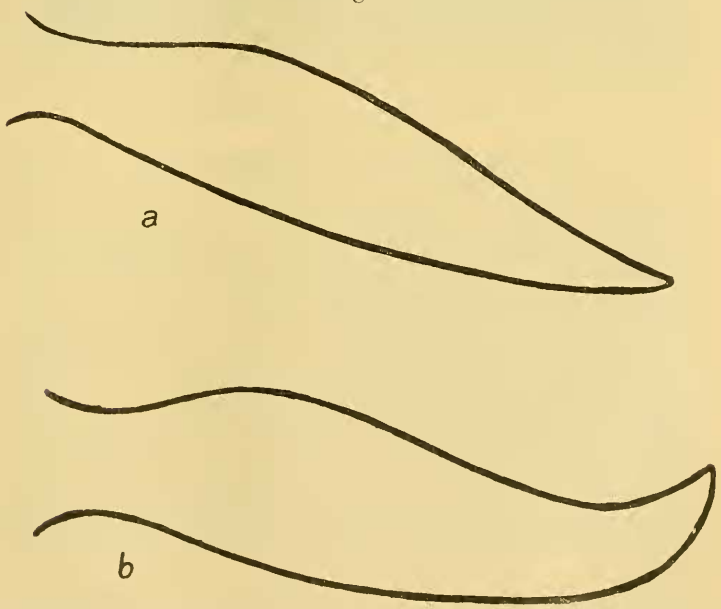
remarkably free from parasites, the only species found being *Balænophilus unisetus* Aurivillius on the baleen plates. No internal parasites could be found.

Text-fig. 76.



orsal fins of *a. Balænoptera musculus* Linnæus; *b. Balænoptera sibbaldii* Gray.

Text-fig. 77.



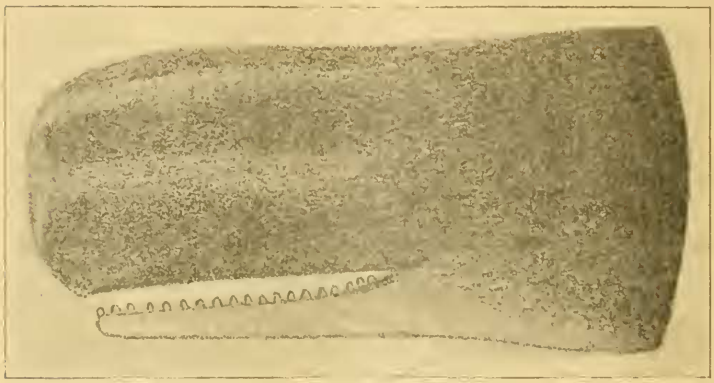
Paddles of *a. Balænoptera musculus* Linnæus; *b. Balænoptera sibbaldii* Gray.

3. Physeter macrocephalus Linnæus *.

Two male Sperm Whales were captured during my visit. Their general appearance corresponded with the descriptions of previous observers. But, as there seems to be a little uncertainty concerning the shape of the head of this whale, a sketch is given (text-fig. 78) of the form of the head in the Innishkea specimens.

The upper part of the animal was black, the ventral surface and lower jaw a light bluish grey. A white oval patch occurred in the middle of the ventral surface, extending from a point just in front of the navel to the anus.

Text-fig. 78.



View of the left side of the head of *Physeter macrocephalus* Linnæus.

On the surface of the head of one of the specimens, on the left side immediately over the position of the nasal bone of the skull, there was a small groove-like depression about two inches deep and five inches long. This slit was placed longitudinally and in a straight line with the blow-hole. It may possibly have been a vestige of an old nasal opening which was situated further back than the present position of the blow-hole.

One of these whales had 24 teeth on each side of the lower jaw. Six of those on the right and eight on the left side were broken. No sign of teeth could be found in the upper jaw.

The alimentary canals of the two Sperm Whales contained the remains of cuttlefish, and the marks of their horny denticulate suckers could be seen all over the surface of the lower jaw and extending more than half-way up the head of each whale, from its anterior extremity to the paddles. The marks of the suckers varied from faintly dotted circular imprints, formed by the slight

* Probably synonymous with *P. catodon* Fabricius; *P. gibbosus* Schreber; *P. trumpo* Gerard; *P. polycistus* Couch; *Catodon australis* MacLeay; *C. colneti* Gray; *P. polycyphus* Quoy and Gaimard.

impress of the horny teeth of the suckers upon the epidermis, to deep circular cuts reaching to the blubber. In many cases the epidermis had peeled off from within the deeply cut circles, exposing the corium. The circles varied in diameter from $\frac{1}{4}$ inch or less to $1\frac{1}{2}$ inches according to the size of the sucker which formed them. These marks were noticed by Pouchet and Beauregard * as occurring on the head of a Sperm Whale and were attributed by them to parasitic Cirripedes which had become detached. But, after comparing these marks with the horny rings of the suckers taken from the stomachs and intestines of the two specimens, and taking into account the fact that the marks only occur on the head, there can be no doubt that they were made by cuttlefish during their struggles with the Sperm Whales who had seized them for food. The marking of the skin of Odontocetes by cuttlefish has been referred to by Dr. Harmer †.

A group of barnacles was found attached to the fourth anterior tooth on the right side of the lower jaw of one of these whales. The cluster consisted of individuals of *Conchoderma auritum*, to one of which was attached a small specimen of *C. virgatum*. These were the only external parasites to be seen on the two Sperm Whales.

The guts of both specimens were infested with internal parasites. The determination of these is in progress.

Several of the whales were fresh enough to have permitted an examination to be made of their histology and of their gut Protozoa; but unfortunately the necessary apparatus for such work was not at hand at Innishkea. This was to be regretted since the gut Protozoa of the Cetacea are quite unknown and very little, if anything, has been written upon the histology of whales.

VII. Miscellaneous Observations.

1. *Locality of Captures.*

When the station at Innishkea was first opened in the early summer of 1908, whales were taken at a distance of ten miles from the island. But during the season of 1909 the steamers had to go at least sixty miles out to sea before they could find a whale. It was not possible to obtain the exact latitude and longitude of the captures, as these were kept as trade secrets by the whalers. However, it is safe to say that all the whales obtained by this station during the two seasons of its existence were taken within a radius of seventy miles, north, south and west of Innishkea. This can be explained either by their being molested or by an alteration in the distribution of their food.

During my visit one of the whaling captains discovered about twenty individuals of *Balænoptera musculus* occupying the head

* Pouchet et Beauregard, Nouvelles Archives du Muséum (Paris), 3 sér. vol. i. 1889, p. 9.

† Harmer, Trans. Norfolk and Norwich Naturalists' Soc. vol. vii. 1901, p. 185.

of an inlet or bay about sixty miles north-west of Innishkea within the 1000 fathom contour. He hunted this spot for three weeks, always finding the whales there, and was still doing so when I left. I took an opportunity of visiting the place with him about the middle of August and was impressed with the apparent regularity in the habits of the animals. Between daybreak and 10 A.M. they were to be seen swimming in this deep inlet and blowing every ten minutes. After 10 A.M. they disappeared for the rest of the day, but were all back again in the same place the next morning. The captain always appeared on the ground at daybreak, killed one or two and towed them home during the day, returning to the locality over night.

It is maintained by the whalers that the *Balænoptera* spend several hours near the surface each day blowing every ten minutes and storing their blood and lungs with air, and that they then go down and remain below for perhaps eight or twelve hours at a time. They are said to avoid the heat of the day by remaining under water during that period and appearing at the surface in the early morning and evening. On dull cold days they may be at the surface at any time during the day, though they are most plentiful at sunrise. Mr. Collett * appears to have been given the same account by whalers. The explanation of these habits attributed to the *Balænoptera*, if they really occur, may be the rising and sinking of the plankton eaten by the Crustaceans which form the staple food of these whales. It is more likely that the mid-day heat may have some effect on the plankton, and thus affect the whales indirectly, than that there should be any direct influence.

2. *Diving Powers.*

I made enquiries of the whalers on this subject and I was told that whales, when struck by the harpoon, often dive to the bottom and sometimes come up with stones adhering to the ventral surface. This, however, has been denied by other whalers. During my visit I found on the under surface of one of the specimens of *B. musculus* landed at Innishkea a few broken spines of Echinoderms, which had pierced the epidermis and were lying between it and the corium. A harpooned whale is said to have come to the surface with stones attached to its under surface when killed at a locality where the depth was given as 100 fathoms on the chart. If a naturalist were to spend sufficient time on board a whaling steamer he could probably settle this point, for the whales, when dead, always turn over on their backs and float with the ventral surface uppermost, so there would be no difficulty in detecting any adhering stones if they were present. Assuming that a harpooned whale does not act very differently as regards diving powers to one under normal conditions, this would be a simple method of ascertaining what those powers are. Of course

* Collett, Proc. Zool. Soc. 1886, p. 263.

the objection will be raised that if stones are found on the under surface, how is one to make sure how long they have been there? On this point I was assured by my informant that the stones are generally so lightly attached that they soon fall off, and a whale could not travel far with them. If we may assume that this is correct, when a whale is captured with stones on the ventral surface it is only necessary to ascertain the depth of the sea at the locality of capture, by referring to the chart, to ascertain the depth to which the creature has dived on being harpooned. It is said by the whalers that when a harpooned whale, after breaking the harpoon-rope, dives to a depth of 60 fathoms and dies, it comes to the surface at the end of three days; whereas if it goes below this depth and dies it never reappears. There seemed to be unanimous agreement among the whalers upon this point.

3. *Copulation, Period of Gestation and Rate of Breeding.*

The *Balænoptera* are said by whalers to copulate at the surface of the sea. The pair swim towards each other and turn slightly on their sides so that their ventral surfaces face one another. The male makes several dashes at the female to insert the penis. When the pair first rush together the long axes of their bodies are parallel with the surface of the sea; but they curve up vertically at the end of the act. After copulation the male is said to be exhausted and easily caught.

As regards the period of gestation and the rate of breeding among Cetaceans, it is difficult to see how any definite information can be obtained on these and similar subjects, which are of interest to the cetologist and of considerable importance commercially, unless individuals are kept in a confined place for purposes of observation. This would perhaps not be such an impossible undertaking as it would at first appear. Of the many deep sounds or straits, through which the tides pass, on the western coasts of Ireland and Scotland, one could doubtless be found which could be converted into an aquarium for whales. To do this it would only be necessary to place barriers at the mouths of the strait in order to imprison the animal and yet allow of the ingress and egress of the tide and food-supply. The animals would have to be caught by the Japanese method of capturing whales, which consists of throwing a large rope-net over the animal and towing it to the shore alive. *Balæna biscayensis* Gray, has been taken by this method and possibly other species also *.

A Whalebone Whale imprisoned in a strait could probably be kept alive on the organisms swept in by each tide.

Until some such scheme as this is brought to pass we must continue to remain in ignorance, or be content with vague speculations, concerning many points in the biology of the larger Cetacea.

* K. Möbius, Sitzungsberichte der Akademie der Wissenschaften zu Berlin, lii. 1893.

EXPLANATION OF PLATE LXXIV.

Fig. 1. Posterior view of the right tympanic membrane of *Balænoptera musculus* Linnæus, showing its attachment to the malleus.

a. Head of malleus with the two articular surfaces for the incus.
b. Manubrium of malleus.
c. Processus longus of malleus.
d. Portion of the lip of the tympanic bone to which the processus longus of the malleus is fused.
e. Ligament of tympanic membrane.
f. Sac-like tympanic membrane.
g. Portion of the mucous membrane lining the tympanic cavity.
h. Wall of external auditory canal which has been cut near its junction with the rim of the tympanic membrane-sac.

Fig. 2. Plug of ear-wax from the external auditory meatus of *Balænoptera musculus* Linnæus. A. Dorsal view of plug. B. Posterior view.

a. Cup-like portion for the reception of the tympanic membrane.
b. Flattened distal portion.

Fig. 3. Ventral view of the left tympanic bone and inner portion of the external auditory meatus of *Balænoptera musculus* Linnæus.

a. Inner portion of external auditory meatus with the ventral wall removed to show the tympanic membrane and plug.
b. Plug of ear-wax.
c. Tympanic membrane.
d. Tympanic bone.

2. Zoological Results of the Third Tanganyika Expedition, conducted by Dr. W. A. Cunnington, F.Z.S., 1904–1905.—Report on the Rotifera. By Charles F. Rousselet, F.R.M.S.*

[Received April 7, 1910.]

(Plate LXXV.†)

Amongst the collections brought back by Dr. W. A. Cunnington from the great inland lakes of Central Africa, visited during this Expedition, were a number of tubes containing fine surface Plankton nettings which I have searched over for Rotifera.

The gatherings were not specially made with a view to collect these creatures, and being, moreover, made only from a boat in the open water and never among the vegetation near the shore, these circumstances may account for the comparatively poor results obtained.

The Collection is, however, interesting and important from the fact that, with the exception of 8 species (excluding doubtful ones) collected in and near the Victoria Nyanza by Dr. Stuhlmann in 1891 and described by Dr. Ant. Collin (1) in 1896, and 14 additional species (again excluding the doubtful ones) collected in the Victoria Nyanza by Dr. Borgert in 1904, and described by Prof. E. von Daday (2) in 1907, no previous records of Rotifera

* Communicated by Dr. W. A. Cunnington, F.Z.S.
† For explanation of the Plate see p. 799.